A/S NORSKE SHELL

WELL: 31/2-14

PVT - STUDY

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CONTENTS

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Reservoir Fluid Study
Well: 31/2-14
Recombined Sample
Bottle no. 811089 (oil)
and no. A 1014 (gas)

S U M M A R Y

This report present the results of a PVT-study of a recombined sample of reservoir fluid from well: 31/2-14.

Separator gas and liquid samples were analysed and recombined according to a bubble point pressure of 2295 psia.

Single-stage flash, gas composition, viscosity, differential liberation pressure-volume relations and separator tests were determined on the recombined sample at 68.3°C.

Main results are:

Bubble point at 68.3°C	:	157.0 barg
Density at bubble point	:	787.4 kg/m^3
Compressibility at bubble point:		1.20 x 10^{-4} bar^{-1}
Viscosity at bubble point	:	1.845 cp

From single-stage flash:

Gas/oil ratio	:	67.8 Sm^3/m^3
Bo at bubble point	:	1.202 m^3/m^3
Density of oil at 15°C:	:	888.9 kg/m^3

Standard conditions: for gas volumes = 15°C and 1 atm
for oil volumes = 15°C and atmospheric pressure

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SAMPLE

The recombination samples, bottle 811089 (oil) and no. 1014 (gas) were supplied by A/S NORSKE SHELL and contained fluids sampled from the separator on well 31/2-14.
Separator conditions were 150 psig and 142°F. Opening pressure of separator gas sample at 61.3°C were 170 psig. Bubble point of separator oil sample was 148 psig at 142°F.

LABORATORY PROCEDURE

PVT-analysis

Pressure-volume relations were determined in a Ruska visual liquid PVT cell-oil bath at 68.3°C. Single flash to 15°C and atmospheric pressure and separator tests were performed in a Ruska Flash Separator. Gas volumes were measured by a Ruska Gasometer. Gas samples for analysis were collected in a gas sampling tube (250 ml) connected between the separator and gasometer.

Gas analysis

Gas analysis up to and including nonanes was carried out with a Perkin Elmer Sigma gaschromatograph equipped for automatic gas analysis and column switching. The analysis was carried out isothermally at 65°C with FID and hot wire detector at 150 and 100°C respectively. Columns were 1: 15% squalane on Chromosorb P, 2: Poropak N, 3: Molecular Sieve 5 A.

The C_{6+} fraction is determined by backflushing from column 1 through the FID detector. The separation of the hydrocarbon groups in this fraction is performed in a fused silica culumn, WCOT CP^{tm} Sil 5 (0.12). The gaschromatograph is temperature programmed from 50 to 128°C. The determination is done by a FID at 190°C.

The stock tank oil hydrocarbones up to and nonanes were separated in a column filled with 10% SP-2100 Supelcoport in a Sigma gaschromatograph temeperature programmed from 50-290°C. The determination is done by a FID at 210°C. Hydrocarbones from hexanes to nonanes is determined as alkanes.

The system is calibrated before and after the analysis day with a calibration gas (Norsk Hydro A/S) containing hydrocarbons from methane trough pentane, and helium, nitrogen and carbondioxide.

Density and Molecular Weight

Density of stock tank oil was determined at 15°C with an AP Paar Density meter, calibrated with dry air and distilled water before each measurement. Molecular weight was determined by freezing point depression of benzene.

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Viscosity

Liquid viscosities were determined with a ROP rolling ball viscosimeter calibrated with viscosity standards from Cannon Instrument Co.
Gas viscosities are calculated from molecular composition according to Lee, A.L., Gonzales, M.H. and Eakin, B.E., J. Petr. Techn. 1966, 977-1000.

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FLASH SEPARATION OF SEPARATOR LIQUID
TO STOCK TANK CONDITIONS.

Flash conditions : 150 barg, 61.1°C to atmosphere and 15°C.

Gas oil ratio	: 3.22 sm^3/m^3
Gas gravity	: 0.786
Bo at 150 barg	: 1.019 m^3/m^3
Bo at bubble point	: 1.031 m^3/m^3
Density of oil at 15°C	: 887.1 kg/m^3
Density of separator liquid at bubble point	: 863.3 kg/m^3
Molecular weight of oil	: 245
Molecular weight of $C_{10}+$ (calculated)	: 300

Separator gas properties calculated from molecular composition.

Gas gravity (air = 1)	: 0.665
Compressibility factor	: 0.9819

MOLECULAR COMPOSITION OF SEPARATOR LIQUID, SEPARATOR GAS AND MATHEMATICALLY RECOMBINED RESERVOIR FLUID.

Component	Stock tank oil (mol %)	Gas from separator liq. (mol %)	Recombined separator liq. (mol %)	Separator gas (mol %)	Recombined reservoir fluid (mol %)
Nitrogen		0.60	0.02	0.62	0.26
Carbon dioxide		1.93	0.07	1.38	0.60
Methane		70.04	2.54	86.18	36.39
Ethane	0.17	17.82	0.81	8.04	3.74
Propane	0.39	4.93	0.56	1.66	1.00
iso-Butane	0.85	2.87	0.92	0.97	0.94
n-Butane	0.36	0.68	0.37	0.24	0.32
iso-Pentane	0.87	0.57	0.86	0.25	0.61
n-Pentane	0.24	0.09	0.23	0.05	0.16
Hexanes	2.21	0.26	2.14	0.30	1.39
Heptanes	7.59	0.19	7.32	0.26	4.47
Octanes	9.74	0.01	9.39	0.05	5.61
Nonanes	5.85	0.01	5.64	0.00	3.36
Decanes plus	71.73	0.00	69.13	0.00	41.15

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FLASH OF RECOMBINED RESERVOIR FLUID TO STOCK TANK CONDITIONS

Flash conditions : 300 barg, 68.3°C to atmosphere and 15°C.

Gas oil ratio	: 67.8	sm^3/m^3
Bo at 300 barg	: 1.184	m^3/m^3
Bo at bubble point	: 1.202	m^3/m^3
Density of oil at 15°C	: 888.9	kg/m^3
Density at bubble point	: 787.4	kg/m^3
Molecular weight of oil	: 244	
Gas gravity (air=1)	: 0.692	
Molecular weight of $C_{10}+$ (calculated)	: 288	

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FLASH OF RECOMBINED RESERVOIR LIQUID TO STOCK TANK CONDITIONS.
MOLECULAR COMPOSITION OF RECOMBINED RESERVOIR FLUID.

Component	Stock tank oil (mol %)	Separator gas (mol %)	Recombined reservoir fluid (mol %)
Nitrogen		0.68	0.30
Carbon dioxide		1.36	0.60
Methane		83.60	36.81
Ethane	0.09	8.86	3.96
Propane	0.23	2.34	1.16
iso-Butane	0.54	1.57	0.99
n-Butane	0.24	0.42	0.32
iso-Pentane	0.69	0.44	0.58
n-Pentane	0.19	0.08	0.14
Hexanes	1.85	0.31	1.17
Heptanes	6.63	0.28	3.83
Octanes	8.58	0.06	4.83
Nonanes	5.23	0.00	2.93
Decanes plus	75.73	0.00	42.38

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PRESSURE-VOLUME RELATION AT CONSTANT MASS OF RECOMBINED RESERVOIR LIQUID AT 68.3°C.

Pressure bar gauge	Relative volume V/Vsat	Isothermal compressibility bar^{-1}	"Y"
300.7	0.9848	$0.92 \cdot 10^{-4}$	
275.4	0.9872	$0.97 \cdot 10^{-4}$	
250.6	0.9896	$1.02 \cdot 10^{-4}$	
225.9	0.9922	$1.07 \cdot 10^{-4}$	
201.6	0.9949	$1.12 \cdot 10^{-4}$	
177.4	0.9976	$1.16 \cdot 10^{-4}$	
157.0	1.0000	$1.20 \cdot 10^{-4}$	
148.1	1.0144		4.145
131.1	1.0486		4.035
110.8	1.1101		3.754
88.9	1.2163		3.502
71.9	1.3529		3.308
58.0	1.5318		3.155

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DIFFERENTIAL LIBERATION OF RESERVOIR FLUID AT 68.3°C

Pressure (barg)	Oil Formation Volume Factor B_o (m^3/m^3)	Solution gas oil ratio Rs (Sm^3/m^3)	Gas Formation Volume Factor Bg (m^3/Sm^3)	Density of sat oil (kg/m^3)
300.7	1.172			799.7
275.4	1.175			797.7
250.6	1.178			795.8
225.9	1.181			793.7
201.6	1.184			791.5
177.4	1.187			789.4
157.0	1.190	62.50		787.5 x)
133.1	1.172	53.48	7.95×10^{-3}	794.0
111.1	1.156	45.28	9.64×10^{-3}	799.9
89.1	1.139	36.96	12.17×10^{-3}	806.4
69.3	1.124	29.59	15.31×10^{-3}	812.1
51.2	1.109	22.70	21.55×10^{-3}	818.0
33.4	1.096	15.69	33.18×10^{-3}	823.2
15.5	1.080	8.28	71.24×10^{-3}	829.7
0	1.053			842.2

Residual oil density at 15°C : 886.7 kg/m^3

x) Density at bubble point from single flash: 787.4 kg/m^3

DIFFERENTIAL LIBERATION OF RECOMBINED RESERVOIR FLUID AT 68.3°C

MOLECULAR COMPOSITION OF LIBERATED GASES (MOL %)

Pressure/barg:	133.1	111.6	89.1	69.3	51.2	33.4	15.5	0
Nitrogen	1.80	1.25	0.94	0.68	0.61	0.36	0.33	0.00
Carbon dioxide	0.95	0.99	1.06	1.14	1.28	1.49	1.94	2.42
Methane	92.42	92.70	92.79	92.52	91.43	89.32	83.85	54.09
Ethane	3.45	3.68	3.87	4.23	5.01	6.62	10.22	27.80
Propane	0.59	0.62	0.63	0.69	0.83	1.13	1.94	8.23
iso-Butane	0.32	0.33	0.32	0.34	0.40	0.55	0.95	4.92
n-Butane	0.08	0.08	0.08	0.08	0.09	0.13	0.22	1.02
iso-Pentane	0.08	0.08	0.08	0.08	0.09	0.12	0.19	0.81
n-Pentane	0.02	0.02	0.01	0.01	0.02	0.02	0.03	0.13
Hexanes	0.07	0.07	0.06	0.06	0.07	0.08	0.14	0.36
Heptanes	0.19	0.15	0.11	0.14	0.14	0.14	0.16	0.20
Octanes	0.03	0.04	0.05	0.03	0.03	0.04	0.03	0.02
Nonanes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Decanes-plus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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DIFFERENTIAL LIBERATION OF RECOMBINED FLUID AT 68.3°C

(Gas properties calculated from molecular composition)

Pressure (barg)	Gas viscosity (cP)	Gas Gravity (Air=1)	Compressibility factor, Z
133.1	0.0160	0.609	0.8761
111.1	0.0153	0.607	0.8837
89.1	0.0146	0.607	0.8976
69.3	0.0140	0.609	0.9137
51.2	0.0136	0.617	0.9310
33.4	0.0131	0.633	0.9501
15.5	0.0127	0.672	0.9723
0	0.0114	0.911	0.9968

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VISCOSITY OF RECOMBINED FLUID AT 68.3°C

Pressure (barg)	Viscosity (centipoise)
300.0	2.298
275.0	2.238
247.9	2.148
227.0	2.093
200.6	2.010
177.5	1.906
159.0	1.850
151.8	1.861
121.2	1.978
102.4	2.087
78.8	2.259
57.4	2.493
30.6	2.917
13.4	3.269
0	3.707

SEPARATOR TESTS OF RECOMBINED FLUID AT DIFFERENT PRESSURES AND AMBIENT TEMPERATURE

Separator conditions		Separator GOR	Stock tank GOR	Total GOR	Bo at P_B	Density of tank oil at 15°C	Separator gas gravity
Pressure psig	Temperature °C	sm^3/m^3	sm^3/m^3	sm^3/m^3	m^3/m^3	kg/m^3	Air=1
450	20.0	42.8	17.6	60.4	1.196	886.9	0.626
250	20.0	50.9	9.5	60.4	1.190	886.4	0.614
150	20.0	55.8	6.1	61.9	1.202	887.0	0.628
50	20.0	64.4	1.9	66.3	1.201	889.4	0.647
0 x	15.0			67.8	1.202	888.9	0.692

x From single flash

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SEPARATOR TESTS OF RECOMBINED FLUID AT DIFFERENT PRESSURES AND AMBIENT TEMPERATURE.
Molecular composition of gases liberated from separator (Mol %)

Sep. pressure	450 psig	250 psig	150 psig	50 psig
Nitrogen	1.32	0.82	0.71	0.70
Carbon dioxide	1.32	1.26	1.31	1.35
Methane	89.22	90.66	88.98	86.71
Ethane	6.25	5.92	7.02	8.17
Propane	1.09	0.85	1.20	1.73
iso-Butane	0.51	0.34	0.52	0.89
n-Butane	0.11	0.06	0.10	0.19
iso-Pentane	0.08	0.04	0.07	0.14
n-Pentane	0.01	0.01	0.10	0.02
Hexanes	0.04	0.01	0.03	0.05
Heptanes	0.04	0.03	0.05	0.05
Octanes	0.01	0.00	0.00	0.00
Nonanes	0.00	0.00	0.00	0.00
Decanes plus	0.00	0.00	0.00	0.00

FIG. 1

PRESSURE-VOLUME RELATIONS OF RECOMBINED FLUID AT 68.3 °C

P_b = 157.0 barg

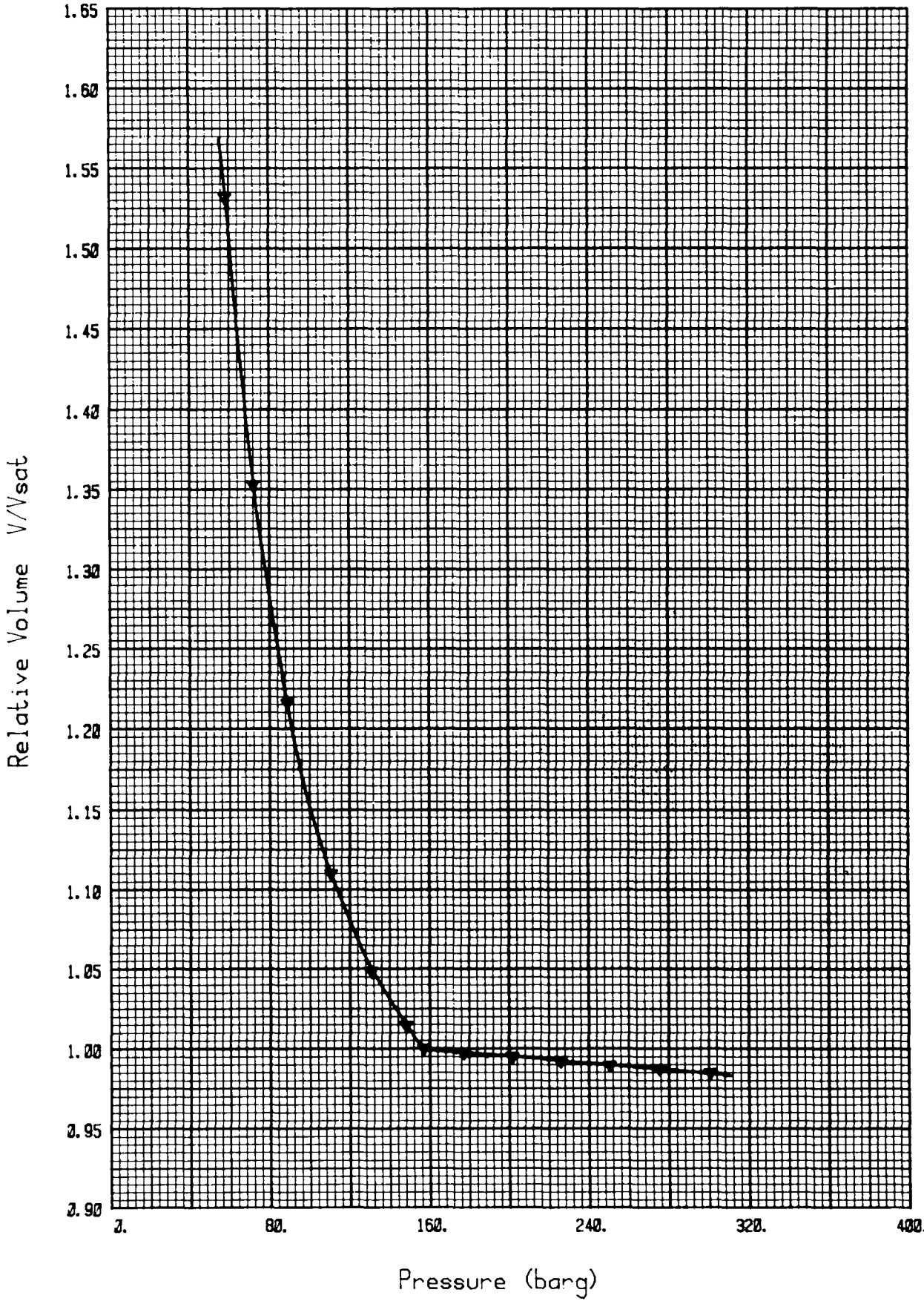

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FIG. 2

DIFFERENTIAL LIBERATION AT 68.3 °C
OIL FORMATION VOLUME FACTOR

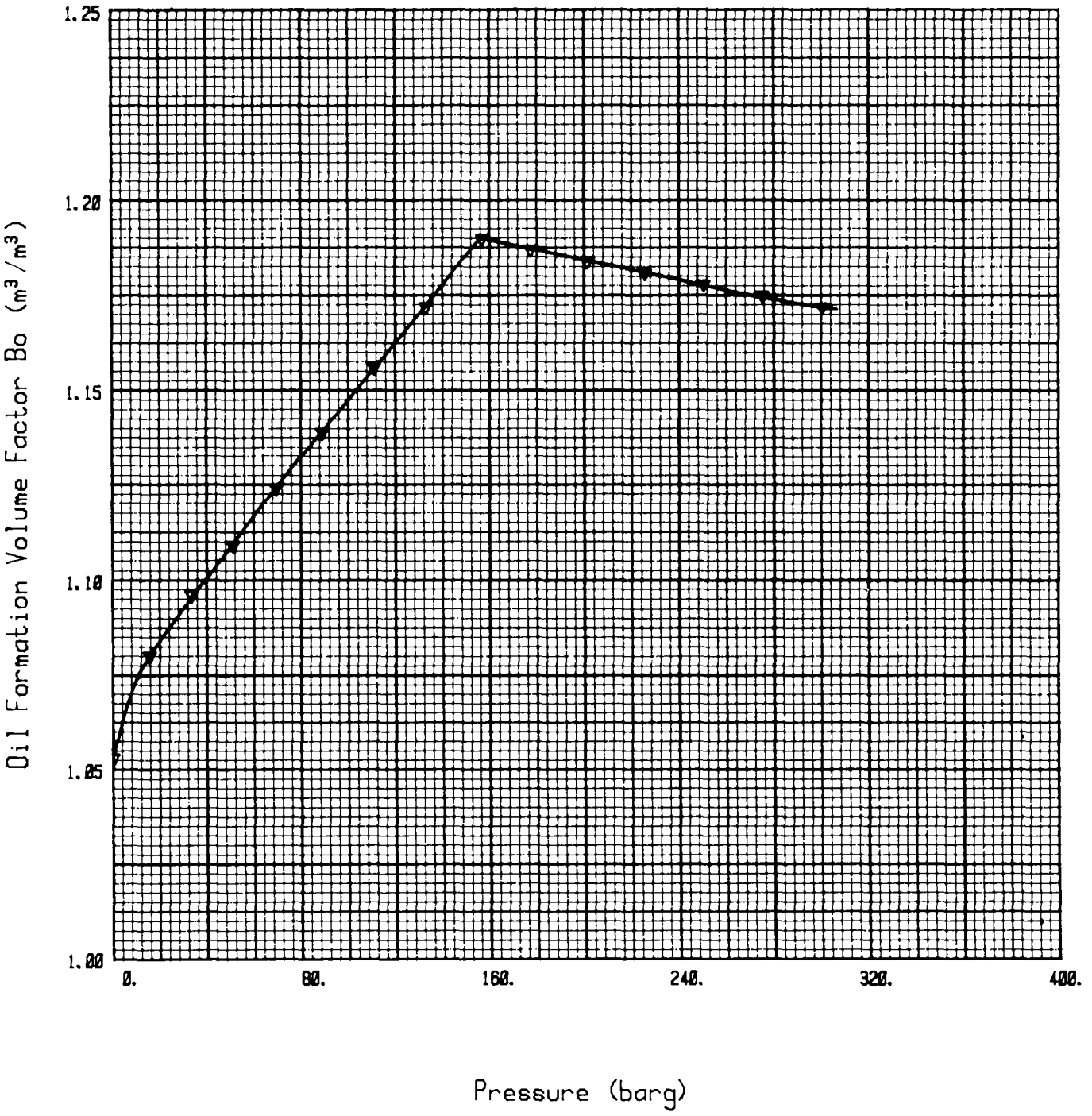

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FIG. 3

DIFFERENTIAL LIBERATION AT 68.3°C
SOLUTION GAS-OIL RATIO

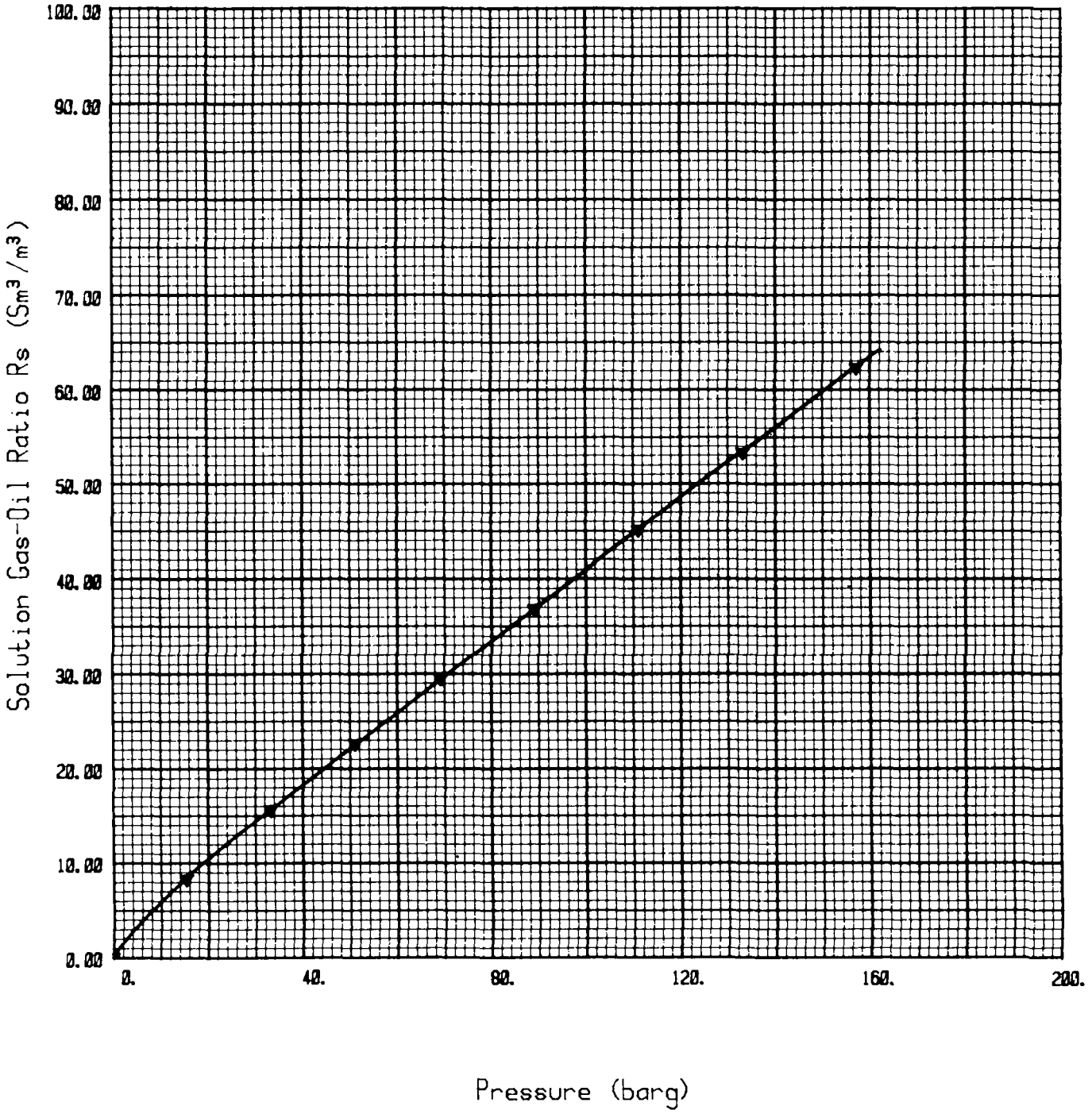

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FIG. 4

DIFFERENTIAL LIBERATION AT 68.3°C
GAS FORMATION VOLUME FACTOR

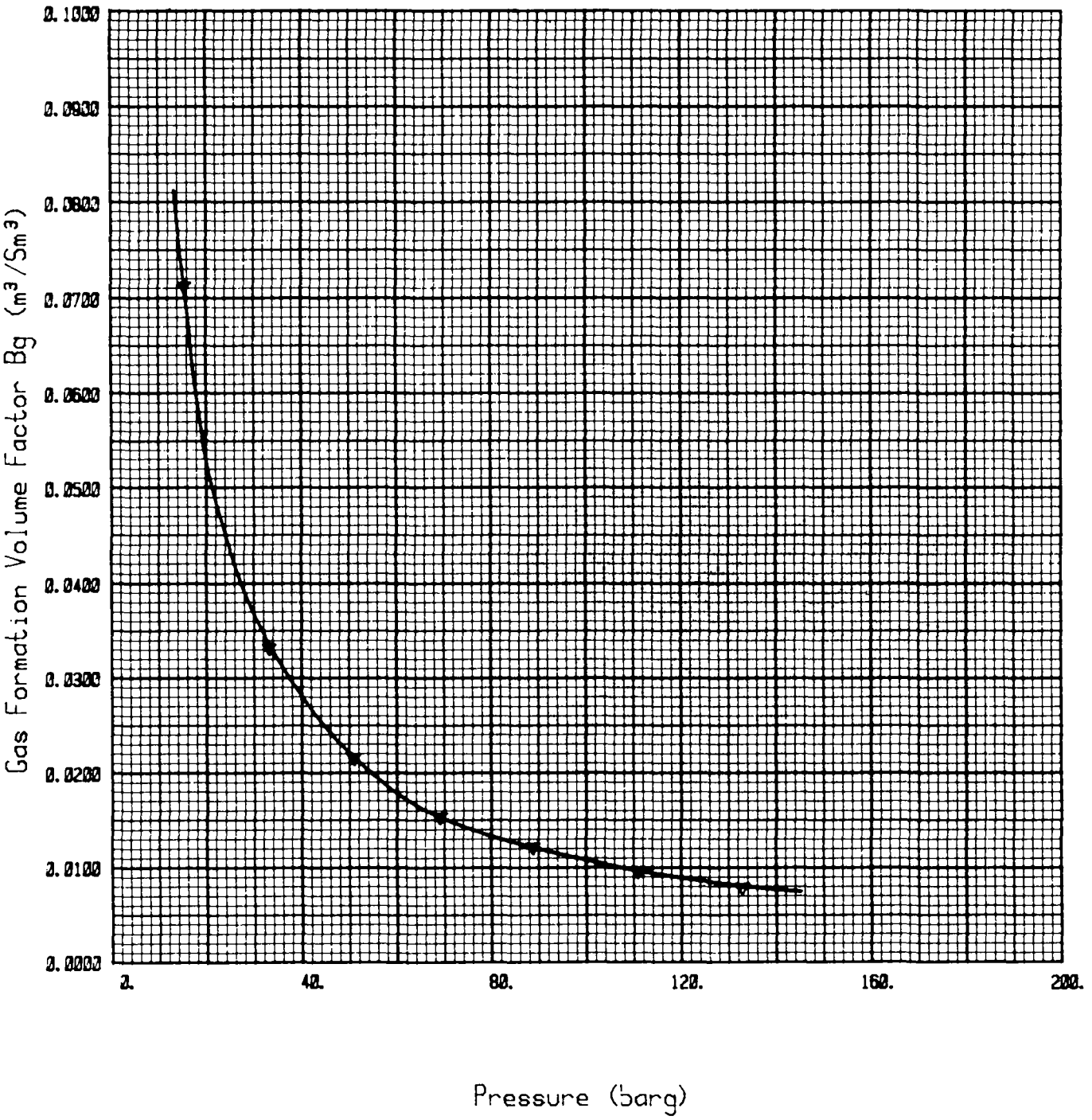

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FIG. 5

DIFFERENTIAL LIBERATION AT 68.3°C
LIBERATED GAS VISCOSITY

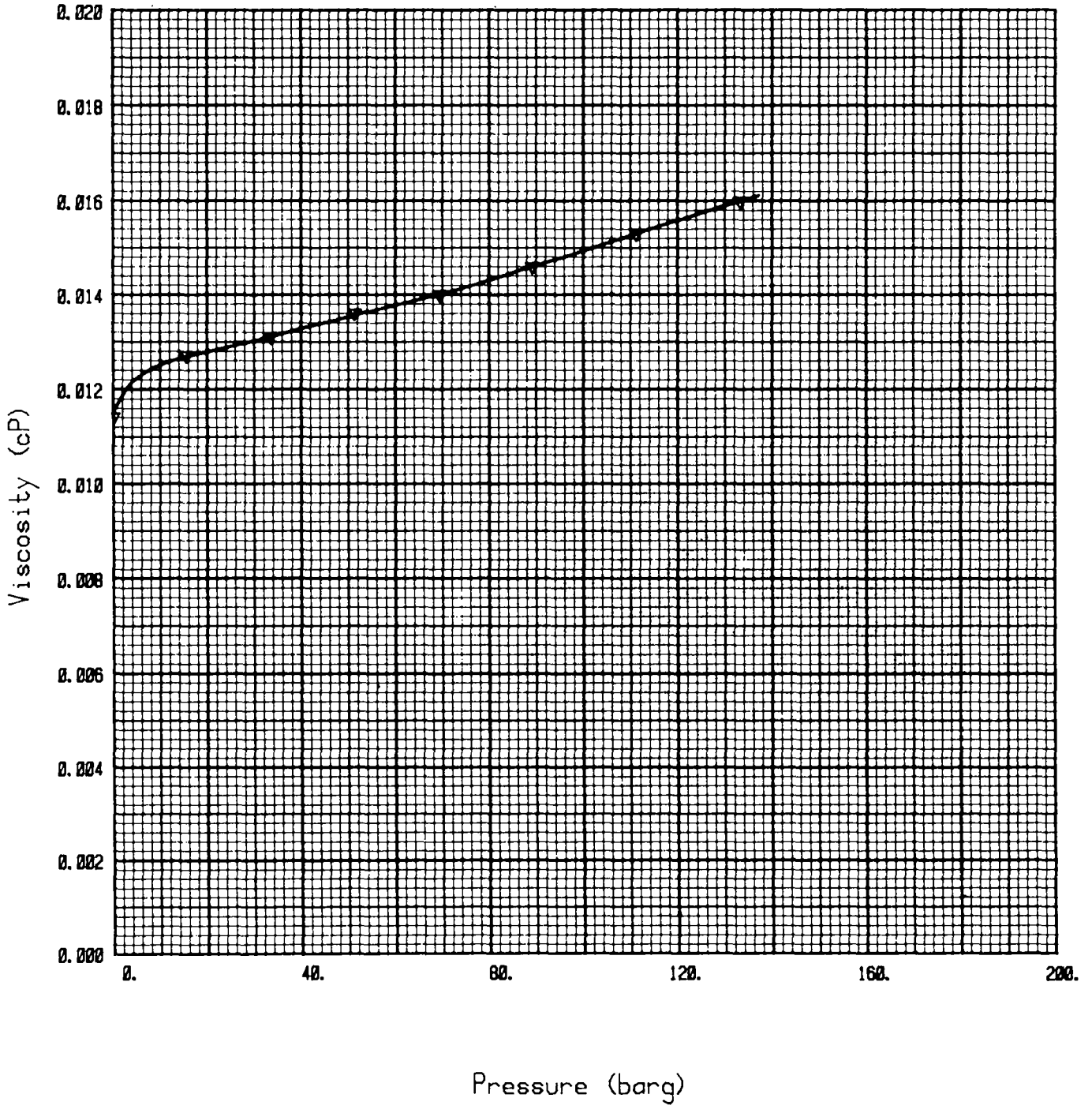

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FIG. 6

DIFFERENTIAL LIBERATION AT 68.3 °C
LIBERATED GAS GRAVITY

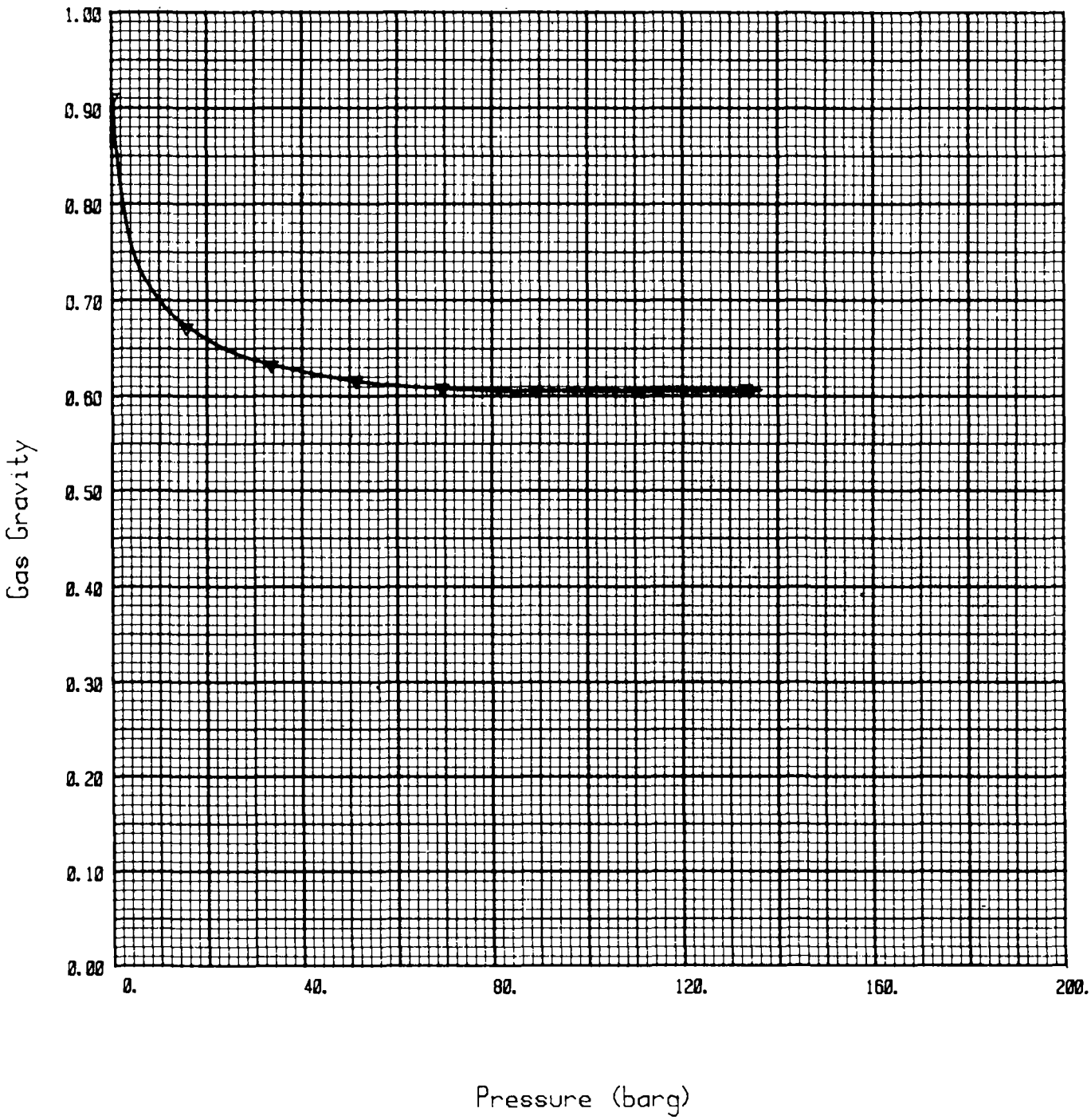

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FIG. 7

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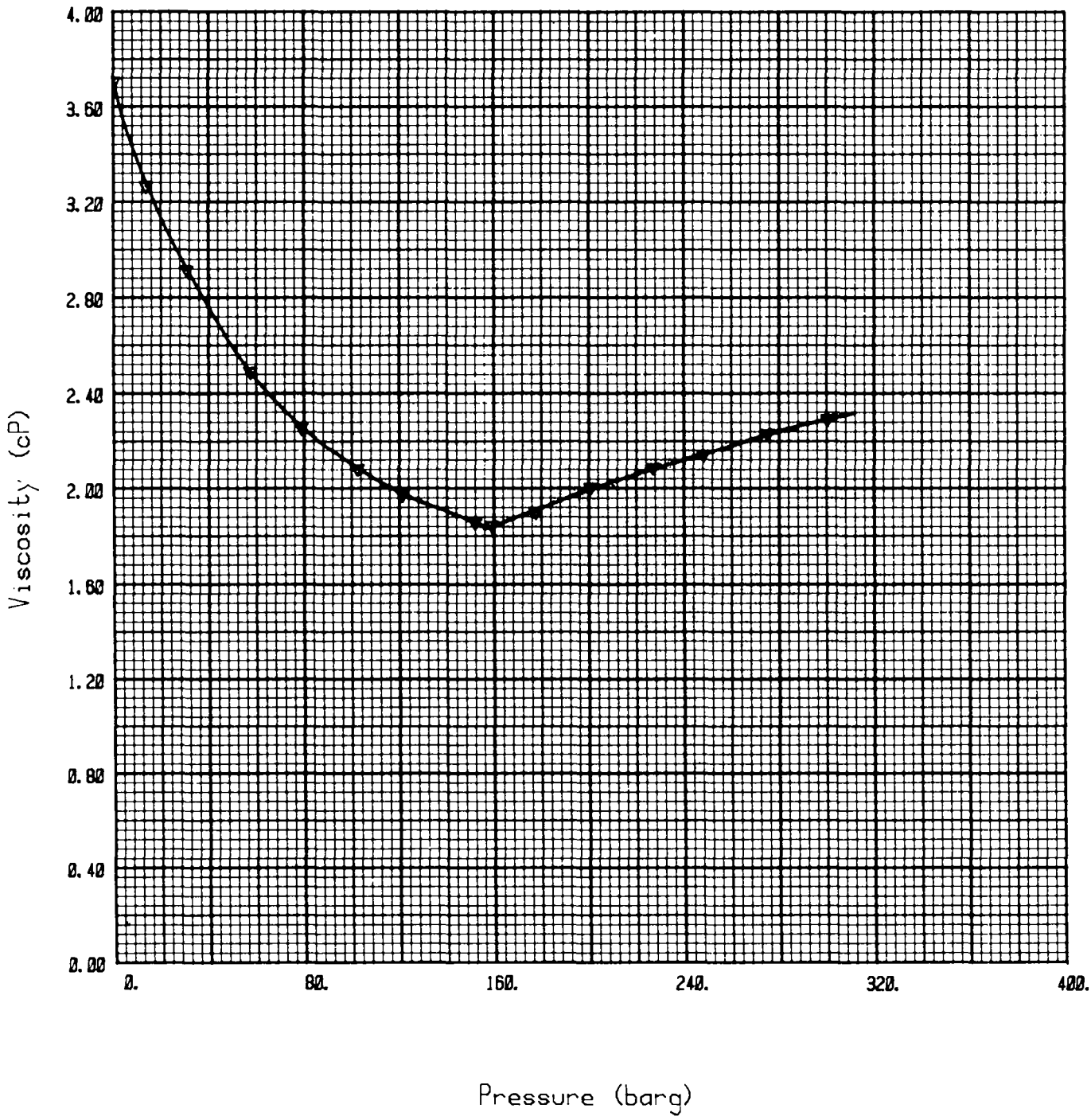
VISCOSITY OF RECOMBINED LIQUID AT 68.3 °C



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